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(54) Starter/generator for motor vehicles

(57) The invention provides a starter/generator which can be disposed on an end of a crankshaft without increasing the length of the crankshaft.
To achieve this, a starter/generator includes a brushless motor 44 having a rotor 15 connected to an end of a crankshaft 12 and a stator including a starter coil 51 and a generator coil 50, a start control means (a three-phase driver 104, a rotor sensor 56, etc.) for converting a battery voltage into AC power and supplying the AC power to the starter coil 51 of the brushless motor 44, and a generation control means (a regulator 52) for supplying electromotive forces induced across the generator coil 50 of the brushless motor 44 to electric loads.

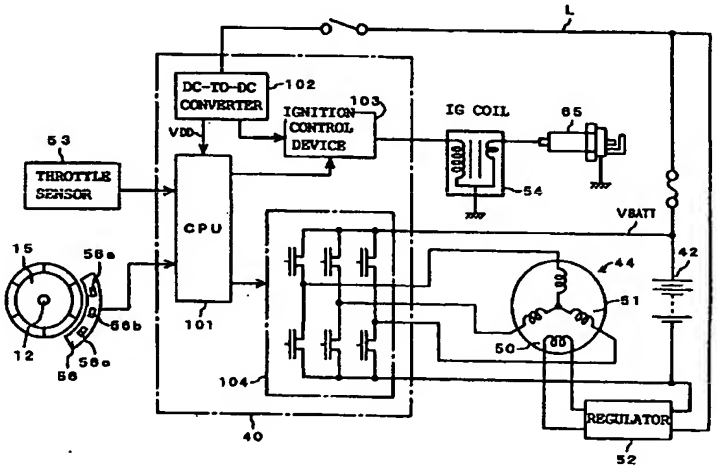

FIG. 7

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Description

[0001] The present invention relates to a starter/generator for a motor vehicle, which comprises an integral combination of a starter and a generator for an internal combustion engine mounted on a motor vehicle, and more particularly to a starter/generator directly connected to the crankshaft of an internal combustion engine.

[0002] As described in Japanese laid-open patent publication No. 10-148142, a starter/generator apparatus used with a conventional internal combustion engine (hereinafter referred to as "engine") has a starter coil and a generator coil which are mounted on the stator of a motor. When the engine is to be started, electric energy is supplied from a battery to the starter coil via a brush mechanism to operate the motor as a starter for thereby rotating a crankshaft directly coupled to the rotor to start the engine.

[0003] The motor has commutator segments held in contact with the brush mechanism through a governor mechanism. When the rotational speed of the engine increases until the rotor reaches a predetermined rotational speed after the engine has started to operate, the governor mechanism operates under centrifugal forces to bring the commutator segments out of contact with the brush mechanism. Subsequently, the motor functions as a generator, and electromotive forces generated across the generator coil are supplied to electric loads and the battery.

[0004] In the conventional starter/generator, a space needs to be provided in the axial direction of the crankshaft for installing the governor mechanism and the brush mechanism, resulting in a corresponding increase in the length of the crankshaft. If four-cycle engines having a camshaft disposed in a cylinder head include a mechanism on the crankshaft for actuating the camshaft, then the length of the crankshaft also needs to be large because of such a mechanism. The length of the crankshaft is also necessarily be large if an automatic transmission mechanism is mounted on an end of the crankshaft. Therefore, if the starter/generator is incorporated in a motor vehicle powered by a four-cycle engine and an automatic transmission mechanism is mounted on an end of the crankshaft, then the crankshaft of the engine is increased in length.

[0005] If the governor mechanism, the brush mechanism, the camshaft actuating mechanism, and the automatic transmission mechanism are positioned closely to each other in order to reduce the length of the crankshaft, then a space for an angular sensor for detecting the angular displacement of the crankshaft cannot be provided on the crankshaft.

[0006] It is an object of the present invention to solve the above conventional problems and provide a starter/generator which can be disposed on an end of a crankshaft without increasing the length of the crankshaft.

[0007] To achieve the above object, there is provided in accordance with the present invention a starter/generator for a motor vehicle, incorporated in a swing unit having a continuously variable transmission unit and a centrifugal clutch connected to an end of a crankshaft of a four-cycle engine, characterized by a brushless motor connected to an opposite end of said crankshaft and control means for controlling starting of the engine and electric generation with said brushless motor.

[0008] According to the above features of the present invention, since the starter/generator can be constructed as a single brushless motor, no governor mechanism and no brush mechanism are required, and an axial area (length) taken up by the starter/generator on the crankshaft can be reduced. Consequently, even if the starter/generator is directly connected to the crankshaft, since any axial extension from the crankshaft is suppressed, the width and weight of the motor vehicle can be reduced.

[0009] The present invention offers the following advantages:

(1) Inasmuch as the brushless motor is used as the generator motor of the starter/generator, and no brush mechanism and no governor mechanism are included, the entire length of the crankshaft can be reduced to a value smaller than the crankshaft of the conventional arrangement, and hence the width of the motor vehicle at the crankshaft and the weight of the motor vehicle can be reduced.

(2) The detected data from the rotor sensor which detects the rotor position of the brushless motor is also used to determine the crankshaft angle. Consequently, no crank sensor is required for detecting the crankshaft angle, and the length of the crankshaft can further be reduced.

[0010] The present invention will hereinafter be described in detail with reference to the drawings.

Fig. 1 is a cross-sectional view of a starter/generator according to an embodiment of the present invention.

Fig. 2 is a fragmentary cross-sectional view of the starter/generator in a swing unit and surrounding components.

Fig. 3 is a fragmentary cross-sectional view of an engine of the swing unit near a cylinder head thereof.

Fig. 4 is a fragmentary cross-sectional view of an automatic transmission (drive unit) of the swing unit.

Fig. 5 is a fragmentary cross-sectional view of the automatic transmission (driven unit) of the swing unit.

Fig. 6 is a side elevational view of a motorcycle incorporating the starter/generator according to the

embodiment of the present invention.

Fig. 7 is a block diagram of a control system of the starter/generator according to the embodiment of the present invention.

[0011] FIG. 6 is a side elevational view of a motorcycle which incorporates a starter/generator according to an embodiment of the present invention. A front motorcycle portion 2 and a rear motorcycle portion 3 are interconnected by a low floor portion 4, and a motorcycle frame including a down tube 6 and a main pipe 7 makes up a motorcycle framework. A fuel tank and a storage box (both not shown) are supported on the main pipe 7, and a seat 8 is disposed above the fuel tank and the storage box. The seat 8 may double as the lid of a luggage box disposed therebelow. The luggage box can be opened and closed by a hinge mechanism disposed in a region FR in a front portion of the seat 8.

[0012] In the front motorcycle portion 2, a steering head 5 is mounted on the down tube 6. A front fork 12A is rotatably supported by the steering head 5 and has an upper end to which a handle 11A is attached and a lower end on which a front wheel 13A is rotatably mounted. The handle 11A has an upper portion covered with a handle cover 33 which doubles as an instrumental panel.

[0013] A link (hanger) 37 is angularly movably supported on an intermediate portion of the main pipe 7. A swing unit 17 is swingably connected to and supported on the main pipe 7 by the hanger 37. The swing unit 17 includes a single-cylinder four-cycle engine 200 mounted in a front portion thereof, and a belt-type continuously variable transmission 35 extending rearwardly from the engine 200. A rear wheel 21 is rotatably supported by a speed reducer mechanism 38 which is connected to a rear portion of the continuously variable transmission 35 by a centrifugal clutch. A rear cushion 22 is interposed between an upper end of the speed reducer mechanism 38 and an upper bent portion of the main pipe 7. The engine 200 has a cylinder head 32 from which there extends an intake pipe 23 connected to the front portion of the swing unit 17. The intake pipe 23 is combined with a carburetor 24 and an air cleaner 25 connected to the carburetor 24.

[0014] The belt-type continuously variable transmission 35 has a transmission case cover 36 from which a kick shaft 27 projects. A kick arm 28 has a proximal end fixed to the kick shaft 27 and a distal end connected to a kick pedal 29. The swing unit 17 has a swing unit case 31 with a pivot shaft 18 mounted on a lower portion thereof, and a main stand 26 is pivotally connected to the pivot shaft 18. When the motorcycle is parked, the main stand 26 is brought into an erected position, as indicated by the chain lines.

[0015] FIG. 1 is a cross-sectional view of the swing unit 17, showing a cross-sectional structure taken along line A - A of FIG. 6. As described in detail later on with reference to FIGS. 2 through 5, the swing unit 17 includes the engine 200 positioned in a front portion thereof, a starter/generator 100 according to the present invention which is connected to an end of a crankshaft 12, and a drive unit 300 and a driven unit 400 of the automatic transmission which is connected to the other end of the crankshaft 12.

[0016] FIG. 2 is a fragmentary cross-sectional view showing structural details of the starter/generator 100 and a crankshaft assembly. The crankshaft 12 is rotatably supported in the swing unit case 31 by main bearings 10, 11, and connecting rods 14 are connected to the crankshaft 12 by crank pins 13. The starter/generator 100 comprises a brushless motor 44, as a main component thereof, which has an inner rotor 15 mounted on an end of the crankshaft 12 which extends out of a crank chamber 9. The inner rotor 15 and a flange member 39 are fastened to the end of the crankshaft 12 by a bolt 20.

[0017] Permanent magnets 19 are fitted over an outer circumferential surface of the inner rotor 15. The permanent magnets 19 are made of a neodymium-iron-boron system. There are six permanent magnets 19 that are disposed at equal angular intervals around the crankshaft 12. The brushless motor 44 has an outer stator 47 disposed around the inner rotor 15 and having a stator core 48 fixed to the swing unit case 31. The stator core 48 has a yoke 49a around which a generator coil 50 and a starter coil 51 are wound.

[0018] A radiator fan 57 is mounted on the flange member 39, and a radiator 58 is disposed in facing relationship to the radiator fan 57. A sprocket 59 is fixedly mounted on the crankshaft 12 between the inner rotor 15 and the main bearing 11. A chain 60 is trained around the sprocket 59 for transmitting power for driving a camshaft (not shown) from the crankshaft 12. The sprocket 59 is integrally formed with a gear 61 which serves to transmit power to a pump for circulating a lubricating oil.

[0019] The swing unit case 31 includes an end 31a having an inner surface to which a base plate 55 is fastened perpendicularly to the crankshaft 12 by a screw 41. A rotor sensor 56 for detecting the permanent magnets 19 mounted on the outer circumferential surface of the inner rotor 15 is mounted on an inner surface of the base plate 55. The rotor sensor 56 comprises a plurality of (three in this embodiment) Hall devices arranged at spaced intervals in an arcuate pattern coaxially with the inner rotor 15, as described later with reference to FIG. 7.

[0020] FIG. 3 is a fragmentary cross-sectional view showing structural details of the cylinder head of the engine 200. Each of pistons 63 disposed in respective cylinders 62 is connected to a small end of one of the connection rods 14 by a piston pin 64. An ignition plug 63 is threaded into the cylinder head 32 and has an electrode assembly exposed in a combustion chamber defined between the head of the piston 63 and the cylinder head 32. The cylinder 62 is surrounded by a water

jacket 66.

[0021] A camshaft 69 rotatably supported by bearings 67, 68 is disposed in the cylinder head 32 above the cylinder 62. An attachment 70 is fitted over the camshaft 69, and a cam sprocket 72 and a reactor 72a for generating cam pulses in connection with a cam sensor 155 are fixed together to the attachment 70 by a bolt 71. A chain 60 is trained around the cam sprocket 72 for transmitting the rotation of the sprocket 59 (see FIG. 1), i.e., the rotation of the crankshaft 12, to the camshaft 69.

[0022] A rocker arm 73 is disposed on the camshaft 69 for swinging movement depending on the cam profile of the camshaft 69 upon rotation of the camshaft 69. The camshaft 69 has exhaust and intake cams integrally formed therewith. A decompression cam 98 engaging the camshaft 69 only in reversely rotatable relationship thereto is disposed adjacent to the exhaust and intake cams. When the camshaft 69 is reversed, the decompression cam 98 is angularly moved to a position projecting beyond the outer profile of the exhaust cam according to the rotation of the camshaft 69.

[0023] Therefore, when the camshaft 69 is rotated in a normal direction, an exhaust valve 96 can be slightly lifted to reduce the load in a compression stroke of the engine. Since a torque required to start to rotate the crankshaft can thus be reduced, the starter for the four-cycle engine can be reduced in size. As a result, the crank assembly can be made compact, and the bank angle can be increased. When the camshaft 69 is rotated in the normal direction for a while, the decompression cam 98 returns to a position within the outer profile of the exhaust cam.

[0024] The cylinder head 32 has a pump chamber 76 defined therein which is surrounded by a water pump base 74 and a water pump housing 75. A pump shaft 78 having an impeller 77 is disposed in the pump chamber 76. The pump shaft 78 is fitted in an end of the camshaft 69, and rotatably supported by a bearing 79. The pump shaft 78 is driven by forces obtained from a pin 80 engaging in a central portion of the cam sprocket 72.

[0025] An air reed valve 94 is mounted in the head cover 81. When a negative pressure is developed in the exhaust pipe, the air reed valve 94 draws air to improve the emission of the engine. Seal members are disposed in positions around the pump chamber 76. These seal members will not be described in detail below.

[0026] FIGS. 4 and 5 are cross-sectional views of the automatic transmission which transmits the rotation of the engine 200 at various speed reduction ratios. FIG. 4 shows the drive unit of the automatic transmission, and FIG. 5 shows the driven unit of the automatic transmission.

[0027] In FIG. 4, a pulley 83 with a V-belt 82 trained therearound is mounted on an end of the crankshaft 12 opposite to the end thereof on which the inner rotor 15 of the starter/generator 100 is mounted. The pulley 83 comprises a fixed pulley cone 83a fixed to the crankshaft 12 against rotation and axial movement, and a movable pulley cone 83b axially slidable with respect to the crankshaft 12.

[0028] A holder plate 84 is positioned behind the movable pulley cone 83b, i.e., behind its surface which is not held in contact with the V-belt 82. The holder plate 84 is mounted for rotation with the crankshaft 12, but is limited against rotation and axial movement with respect to the crankshaft 12. A space surrounded by the holder plate 84 and the movable pulley cone 83b serves as a pocket which accommodates a roller 85 as a governor weight.

[0029] A clutch mechanism for transmitting power to the rear wheel 21 is constructed as follows: In FIG. 5, the clutch has a main shaft 125 supported by a bearing 127 fitted in a case 126 and a bearing 129 fitted in a gear box 128. A pulley 132 has a fixed pulley cone 132a supported on the main shaft 125 by bearings 130, 131. A cup-shaped clutch plate 134 is fixed to an end of the main shaft 125 by a nut 133.

[0030] The pulley 132 has a movable pulley cone 132b mounted on a sleeve 135 of the fixed pulley cone 132a for sliding movement in the longitudinal direction of the main shaft 125. The movable pulley cone 132b engages a disk 136 for rotation therewith around the main shaft 125. A compression coil spring 137 is disposed between the disk 136 and the movable pulley cone 132b for producing repulsive forces in a direction to space the disk 136 and the movable pulley cone 132b from each other. A shoe 139 slidably supported by a pin 138 is mounted on the disk 136. When the rotational speed of the disk 136 increases, the shoe 139 swing radially outwardly into contact with an inner circumferential surface of the clutch plate 134 under centrifugal forces. A spring 140 is provided to bring the shoe 139 into contact with the clutch plate 134 when the disk 136 reaches a predetermined rotational speed.

[0031] A pinion 141 is fixed to the main shaft 125 and held in mesh with a gear 143 fixed to an idle shaft 142. A pinion 144 is fixed to the idle shaft 142 and held in mesh with a gear 146 on an output shaft 145. The rear wheel 21 comprises a rim 21a and a tire 21b fitted around the rim 21a, the rim 21a being fixed to the output shaft 145.

[0032] When the rotational speed of the engine is minimum, the roller 85 is in the solid-line position shown in FIG. 4, and the V-belt 82 is trained around a minimum-diameter portion of the pulley 83. The movable pulley cone 132b of the pulley 132 is displaced to the solid-line position shown in FIG. 5 under the bias of the compression coil spring 137, with the V-belt 82 being trained around a maximum-diameter portion of the pulley 132. At this time, since the main shaft 125 of the centrifugal clutch is rotated at a minimum rotational speed, the centrifugal forces applied to the disk 136 are minimum, and the shoe 139 is retracted inwardly out of contact with the clutch plate 134 by the spring 140. Therefore, the rotation of the engine is not transmitted to

the main shaft 125, and the rear wheel 21 is not rotated.

[0033] When the rotational speed of the engine becomes higher, the roller 85 is displaced outwardly under centrifugal forces. The roller 85 is in the chain-line position shown in FIG. 4 when the rotational speed of the engine is maximum. As the roller 85 is displaced outwardly, the movable pulley cone 83b is pushed toward the fixed pulley cone 83a, displacing the V-belt 82 toward a maximum-diameter portion of the pulley 83. In the centrifugal clutch, the movable pulley cone 132b is displaced against the bias of the compression coil spring 137, displacing the V-belt 82 toward a minimum-diameter portion of the pulley 132. Therefore, the centrifugal forces applied to the disk 136 are increased, causing the shoe 139 to move outwardly into contact with the clutch plate 134 against the bias of the spring 140. As a result, the rotation of the engine is transmitted to the main shaft 125, and then via the gear train to the rear wheel 21. Therefore, depending on the rotational speed of the engine, the diameters of the V-belt 82 around the pulley 83 on the crankshaft 12 and the pulley 132 of the centrifugal clutch are varied to change the speed reduction ratios.

[0034] As described above, when the engine is to start, the starter coil 51 is energized. According to the present embodiment, a kick starter is also employed to start the engine 200 by a kicking action. The kick starter will be described below with reference to FIG. 4. A driven dog gear 86 for starting a kicking action is fixed to a rear surface of the fixed pulley cone 83a. A support shaft 88 having a helical gear 87 is rotatably supported on the transmission case cover 36. A cap 89 is fixed to an end of the support shaft 88 and has a drive dog gear 90 on its end for meshing engagement with the driven dog gear 86.

[0035] A kick shaft 27 is rotatably supported on the transmission case cover 36, and a sector helical gear 91 held in mesh with the helical gear 87 is welded to the kick shaft 27. The kick shaft 27 has an end projecting out of the transmission case cover 36 and having splines that engage splines on the kick arm 28 (see FIG. 6). Reference numerals 92, 93 denote return springs.

[0036] When the kick pedal 29 is depressed, the kick shaft 27 and the sector helical gear 91 are turned against the bias of the return spring 93. The helical gear 88 and the sector helical gear 91 have their helixes oriented such that when the sector helical gear 91 is rotated by depressing the kick pedal 29, it produces thrust forces for urging the support shaft 87 toward the pulley 83. Therefore, when the kick pedal 29 is depressed, the support shaft 87 is displaced toward the pulley 83, bringing the drive dog gear 90 on the end of the cap 89 into mesh with the driven dog gear 86. As a result, the crankshaft 12 is rotated to start the engine 200. When the engine 200 is started, the forces applied to depress the kick pedal 29 are weakened, and the sector helical gear 91 is reversed by the return springs 92, 93, whereupon the drive dog gear 90 is displaced out of mesh with the driven dog gear 86.

[0037] FIG. 7 is a block diagram of a control system of the starter/generator 100. Those reference characters in FIG. 7 which are identical to those described above represent identical or equivalent parts.

[0038] A control unit 40 includes a DC-to-DC converter 102 for converting an output voltage VBATT of a battery 42 into a logic voltage VDD and supplying the logic voltage VDD to a CPU 101, an ignition control device 103 for controlling the supply of electric energy to an ignition coil 54 to energize the ignition plug 65 at a predetermined timing, and a three-phase driver 104 for converting the battery voltage VBATT into three-phase AC energy and supplying the three-phase AC energy to the starter coil 51 of the brushless motor 44.

[0039] A throttle sensor 53 detects a throttle opening θ and supplies the detected throttle opening θ to the CPU 101. The rotor sensor 56 comprises three Hall devices 56a, 56b, 56c, for example. The rotor sensor 56 detects the angular position of the inner rotor 15 as the positions of the six permanent magnets 19 on the outer circumferential surface of the inner rotor 15, and supplies the detected angular position to the CPU 101. A regulator 52 regulates electromotive forces induced across the generator coil 50 depending on the rotation of the inner rotor 15 into the battery voltage VBATT, and supplies the battery voltage VBATT to a power supply line L.

[0040] When the engine starts to operate, the CPU 101 determines the time to energize the starter coil 51 based on the angular position of the inner rotor 15 as detected by the rotor sensor 56, controls the switching timing for power FETs of the three-phase driver 104, and supplies AC power to each of the phases of the starter coil 51.

[0041] The power FETs of the three-phase driver 104 are controlled by the CPU 101 in a PWM mode, and the duty ratio of the three-phase driver 104, i.e., the starting torque of the brushless motor 44, is controlled on the basis of the throttle opening θ as detected by the throttle sensor 53.

[0042] When the started engine 200 reaches a predetermined rotational speed, the supply of electric energy from the three-phase driver 104 to the starter coil 51 is stopped, and the brushless motor 44 is driven by the engine 200. At this time, electromotive forces depending on the rotational speed of the crankshaft 12 are generated across the generator coil 50 of the brushless motor 44. The generated electromotive forces are regulated by the regulator 52 into the battery voltage VBATT, which is supplied to electric loads. Any excessive electric energy from the regulator 52 is stored in the battery 42.

[0043] According to the above embodiment, as described above, since the brushless motor is used as the generator motor of the starter/generator, and no brush mechanism and no governor mechanism are included, the entire length of the crankshaft 12 can be

reduced, and hence the width of the motorcycle which incorporates the starter/generator can be reduced.

[0044] The detected data from the rotor sensor 56 which detects the rotor position of the brushless motor 44 is also used to determine the crankshaft angle. Consequently, no crank sensor is required for detecting the crankshaft angle, and the length of the crankshaft 12 can further be reduced.

[0045] The invention provides a starter/generator which can be disposed on an end of a crankshaft without increasing the length of the crankshaft.

To achieve this, a starter/generator includes a brushless motor 44 having a rotor 15 connected to an end of a crankshaft 12 and a stator including a starter coil 51 and a generator coil 50, a start control means (a three-phase driver 104, a rotor sensor 56, etc.) for converting a battery voltage into AC power and supplying the AC power to the starter coil 51 of the brushless motor 44, and a generation control means (a regulator 52) for supplying electromotive forces induced across the generator coil 50 of the brushless motor 44 to electric loads.

Claims

1. A starter/generator for a motor vehicle, incorporated in a swing unit (17) having a continuously variable transmission unit (35) and a centrifugal clutch (125-140) on an end of a crankshaft (12) of a four-cycle engine, characterized by:

   a brushless motor (44) on an opposite end of said crankshaft and control means (40) for controlling starting of the engine and electric generation with said brushless motor.

2. A starter/generator for a motor vehicle according to claim 1, characterized in that said brushless motor (44) has a stator (47) disposed around a rotor (15) thereof, said rotor being of the inner rotor magnet type with a plurality of permanent magnets (19) disposed on an outer circumferential surface thereof.

3. A starter/generator for a motor vehicle according to claim 2, characterized by:

   a rotor sensor (56) for detecting the magnetism of the permanent magnets (19) disposed on the outer circumferential surface of said rotor (15); and
   control means (40) for detecting an angular displacement of the rotor based on an output signal from said rotor sensor (56) and controlling the supply of electric energy to a starter coil (51) based on the detected angular displacement.

4. A starter/generator for a motor vehicle according to claim 3, characterized by ignition control means (103) for performing ignition control of the engine based on the output signal from said rotor sensor (56).

5. A starter/generator for a motor vehicle, incorporated in a swing unit (17) having a continuously variable transmission unit (35) and a centrifugal clutch (125-140) connected to an end of a crankshaft (12) of a four-cycle engine, characterized by:
   a brushless motor (44 connected to an opposite end of said crankshaft and control means (40) for controlling starting of the engine and electric generation with said brushless motor.

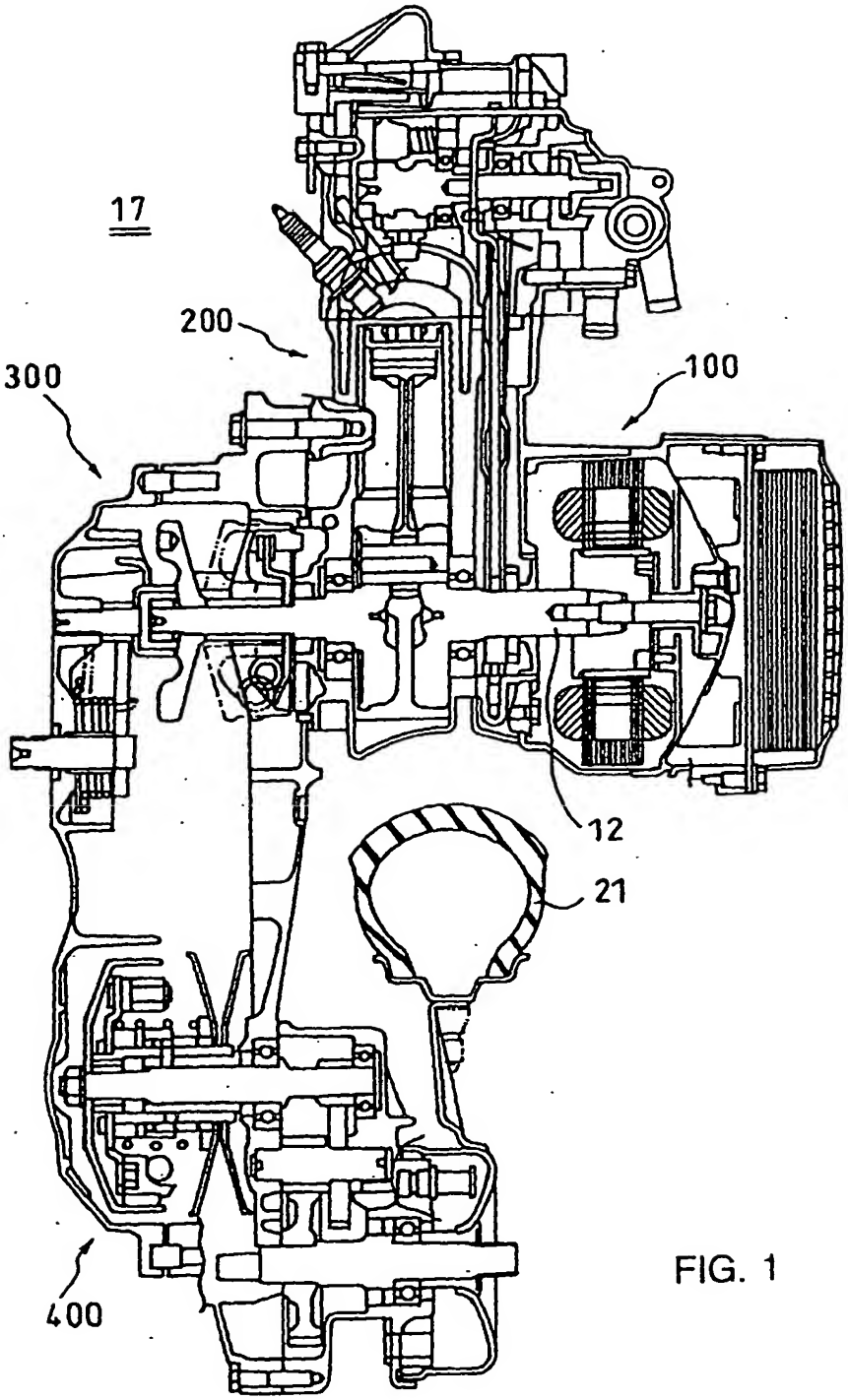

FIG. 1

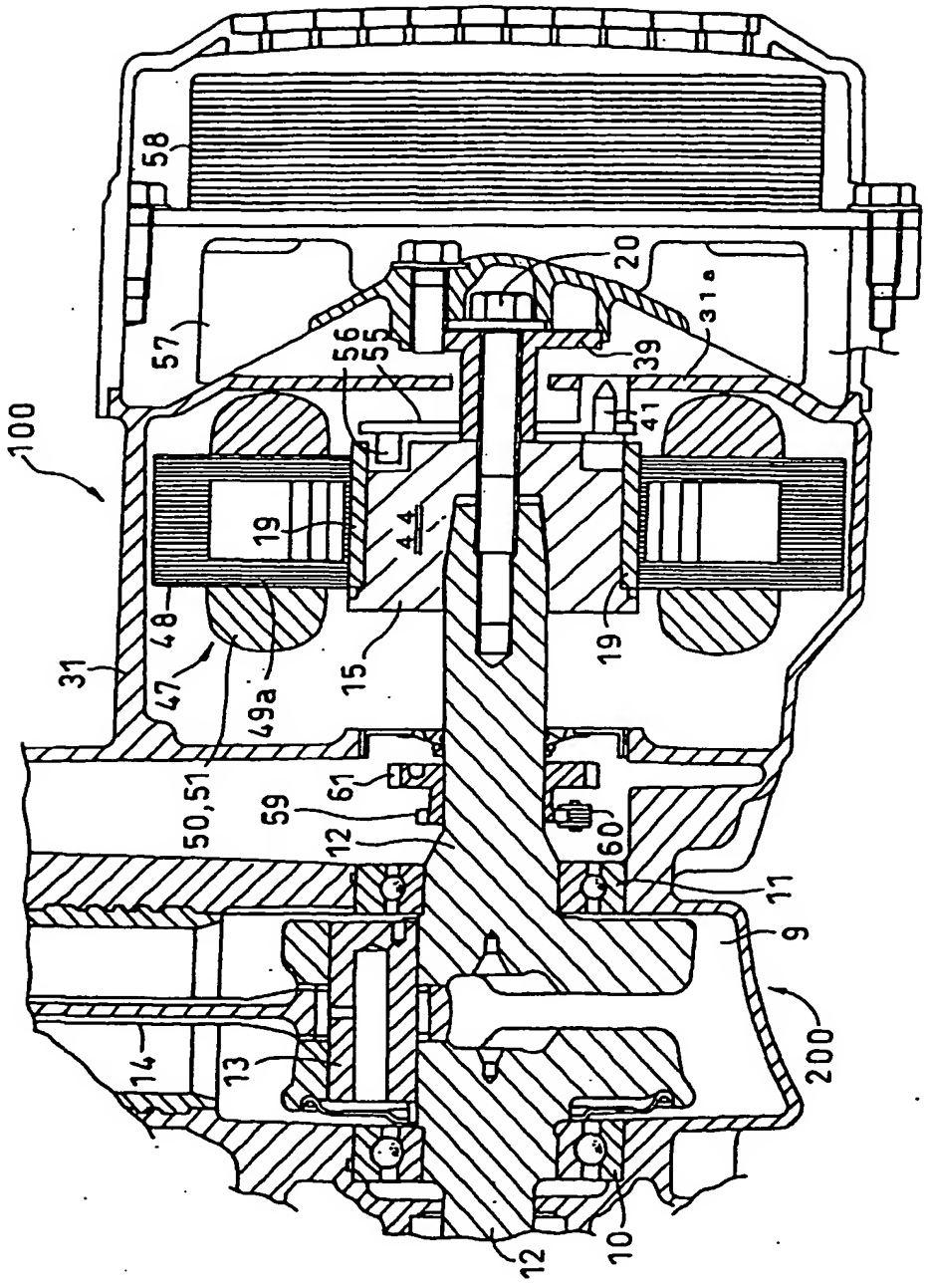
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FIG. 2

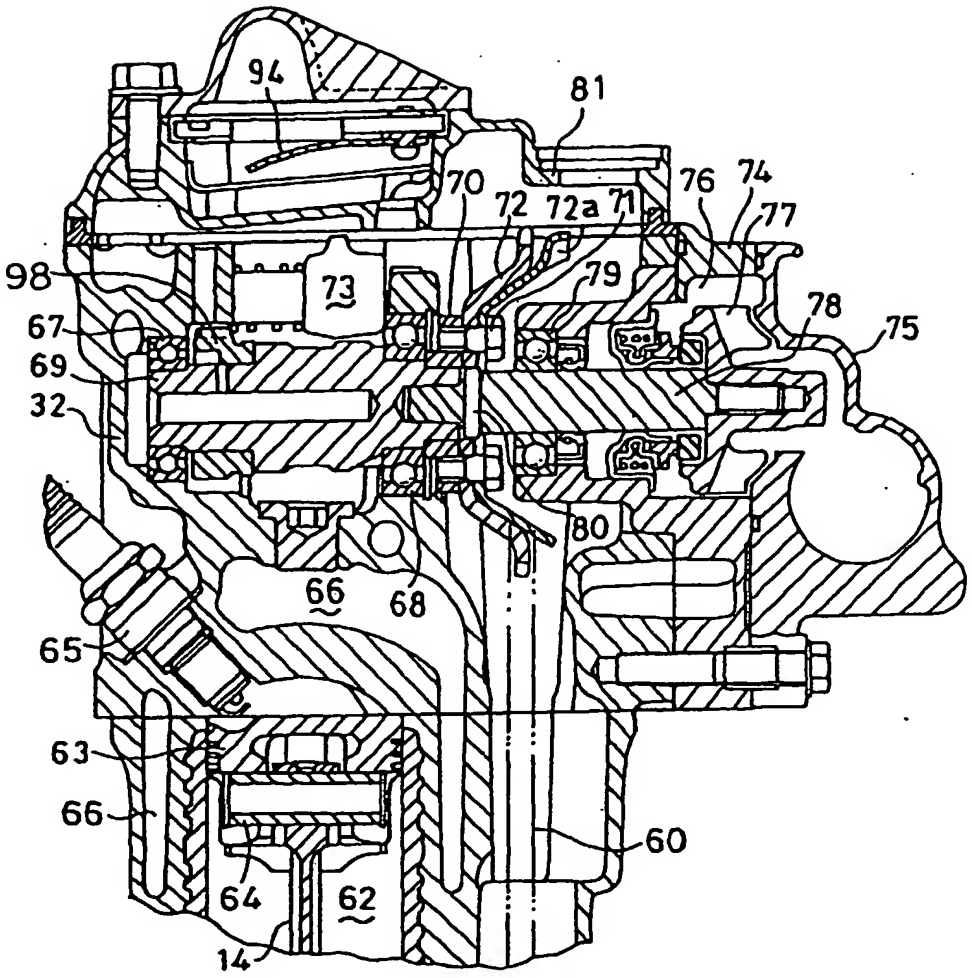
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FIG. 3

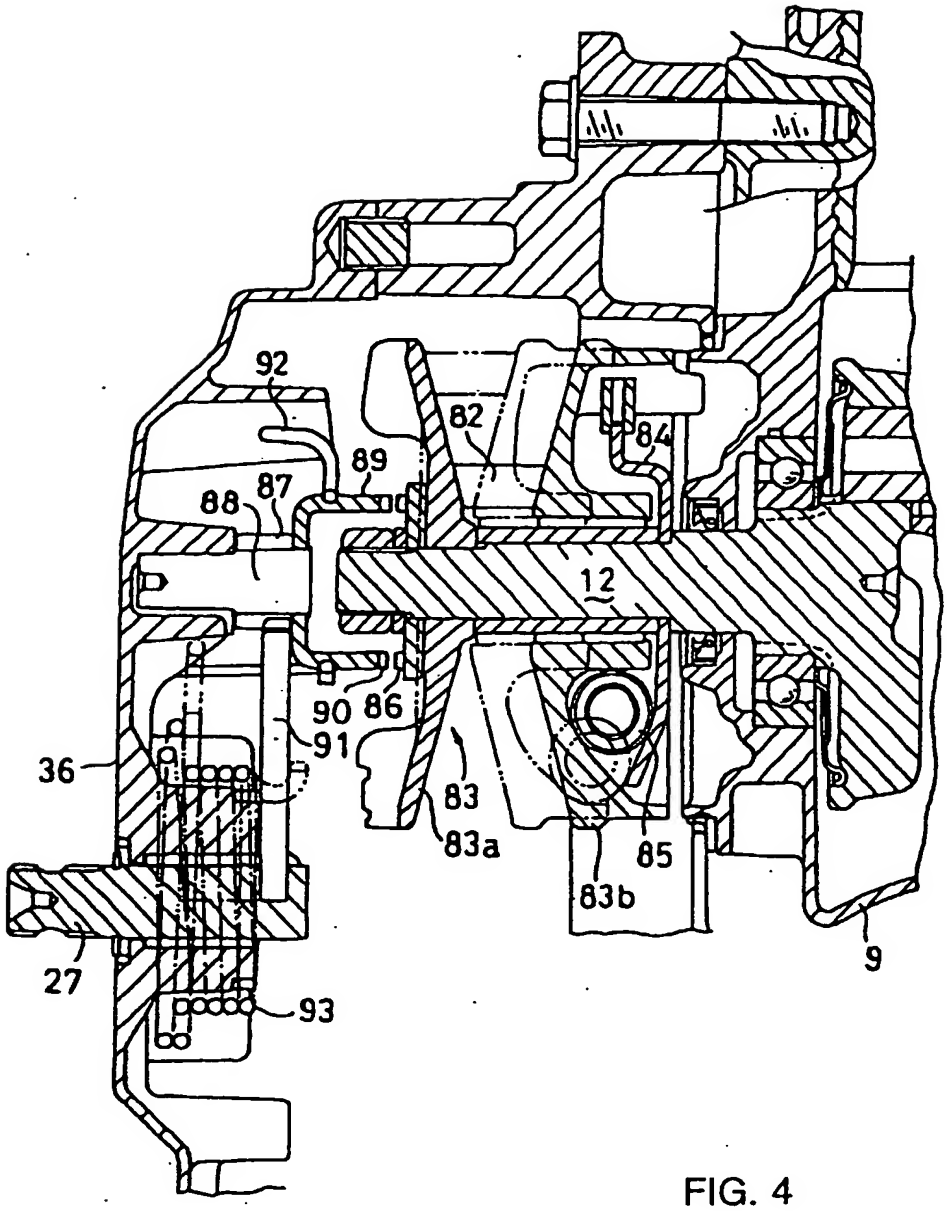

FIG. 4

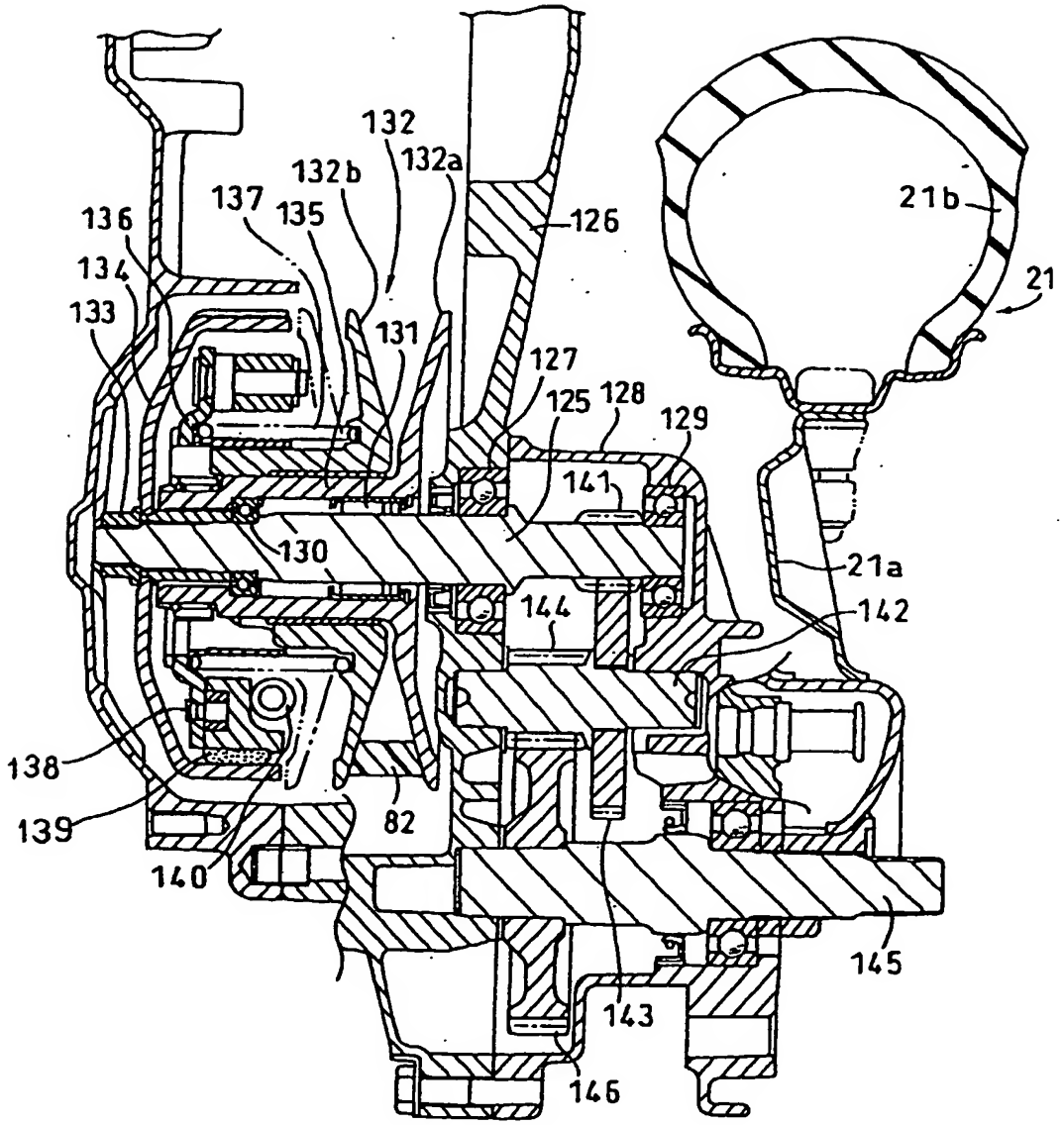
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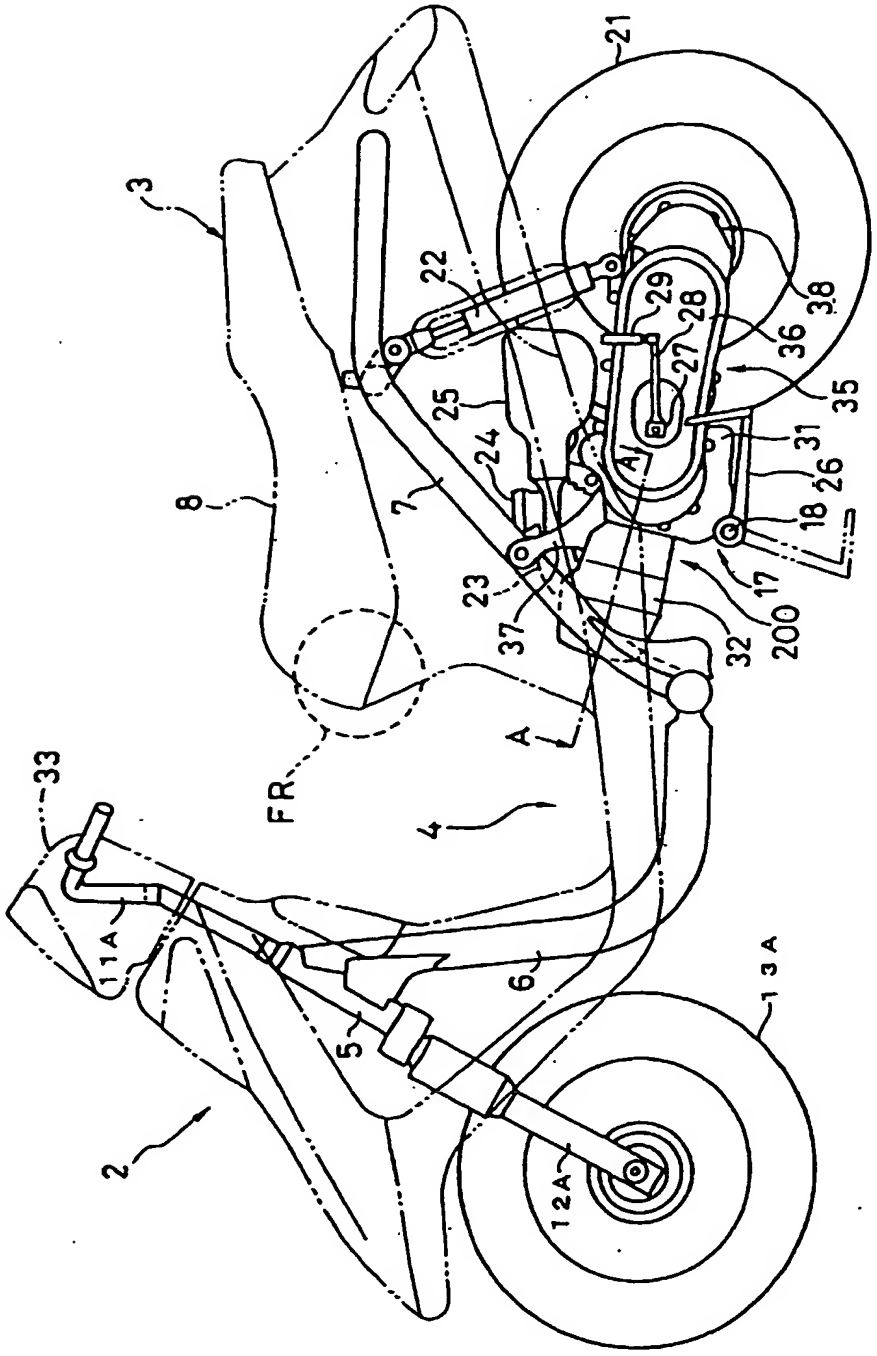
FIG. 5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13A
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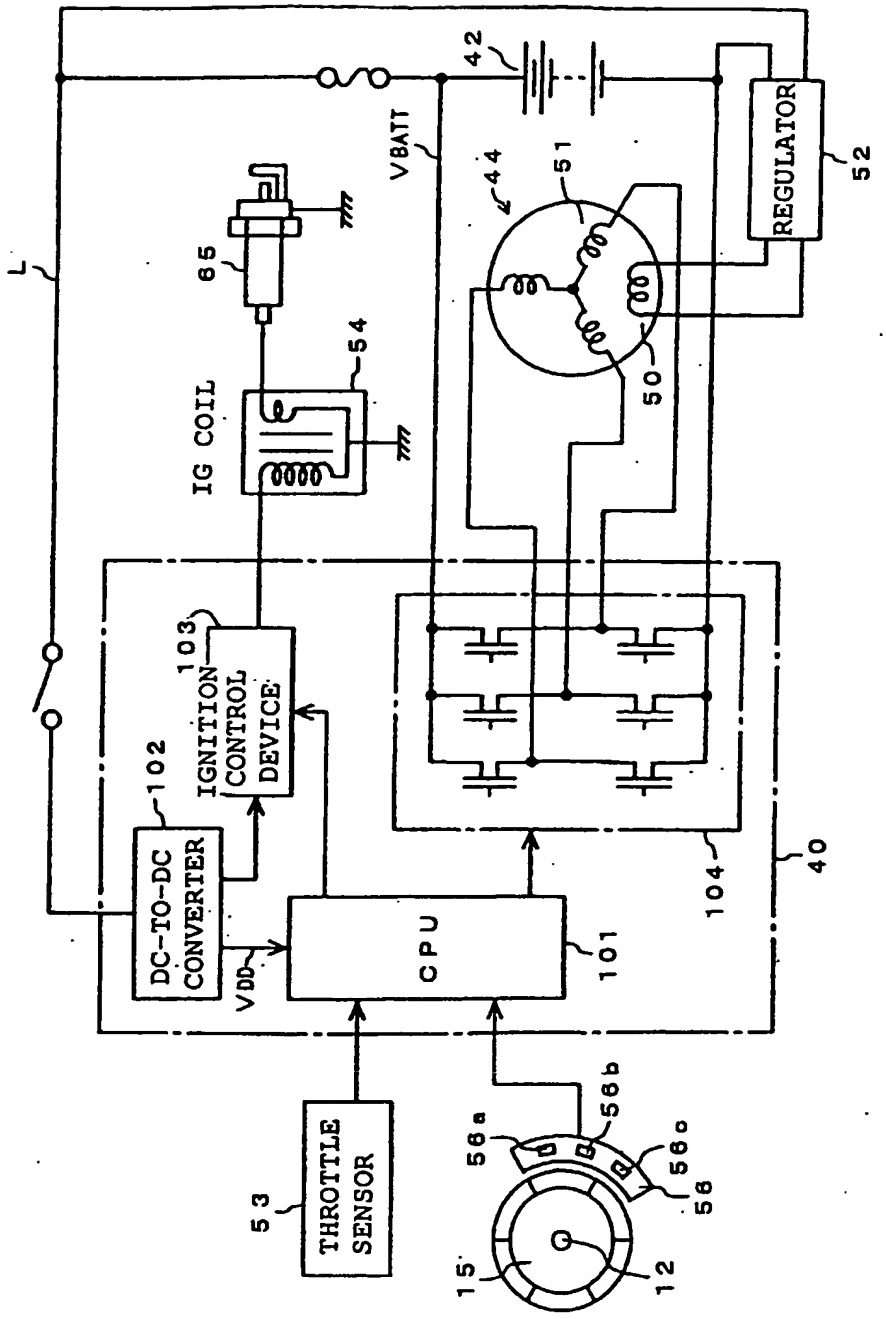
12A

FIG. 6


42
VBATT
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REGULATOR
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L
85
54
IG COIL
50
103
IGNITION CONTROL DEVICE
102
DC-TO-DC CONVERTER
VDD
CPU
101
104
40
53
THROTTLE SENSOR
56a
56b
56c
56
15
12

FIG. 7

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 10 7492

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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